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ATWOOD RESERVOIR, CARROLL AND TUSCARAWAS COUNTIES, OHIO

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

PREPARED FOR
NATIONAL ENVIRONMENTAL RESEARCH CENTER

JUNE 1975

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

ATWOOD RESERVOIR

CARROLL AND TUSCARAWAS COUNTIES

OHIO

EPA REGION V

WORKING PAPER No. 393

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

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REPORT

ON

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OHIO

EPA REGION V

WORKING PAPER No. 393

WITH THE COOPERATION OF THE

OHIO ENVIRONMENTAL PROTECTION AGENCY

AND THE

OHIO NATIONAL GUARD

JUNE, 1975

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Ohio Environmental Protection Agency for professional involvement, to the Ohio National Guard for conducting the tributary sampling phase of the Survey, and to those Ohio wastewater treatment plant operators who provided effluent samples and flow data.

Ned Williams, Director, and Tom Birch, Ken Carr, Larry Dietrick, Ron Havlice, Larry Korecko, Rod Mehlhop, Terry Wheeler, and John Youger, Ohio Environmental Protection Agency, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

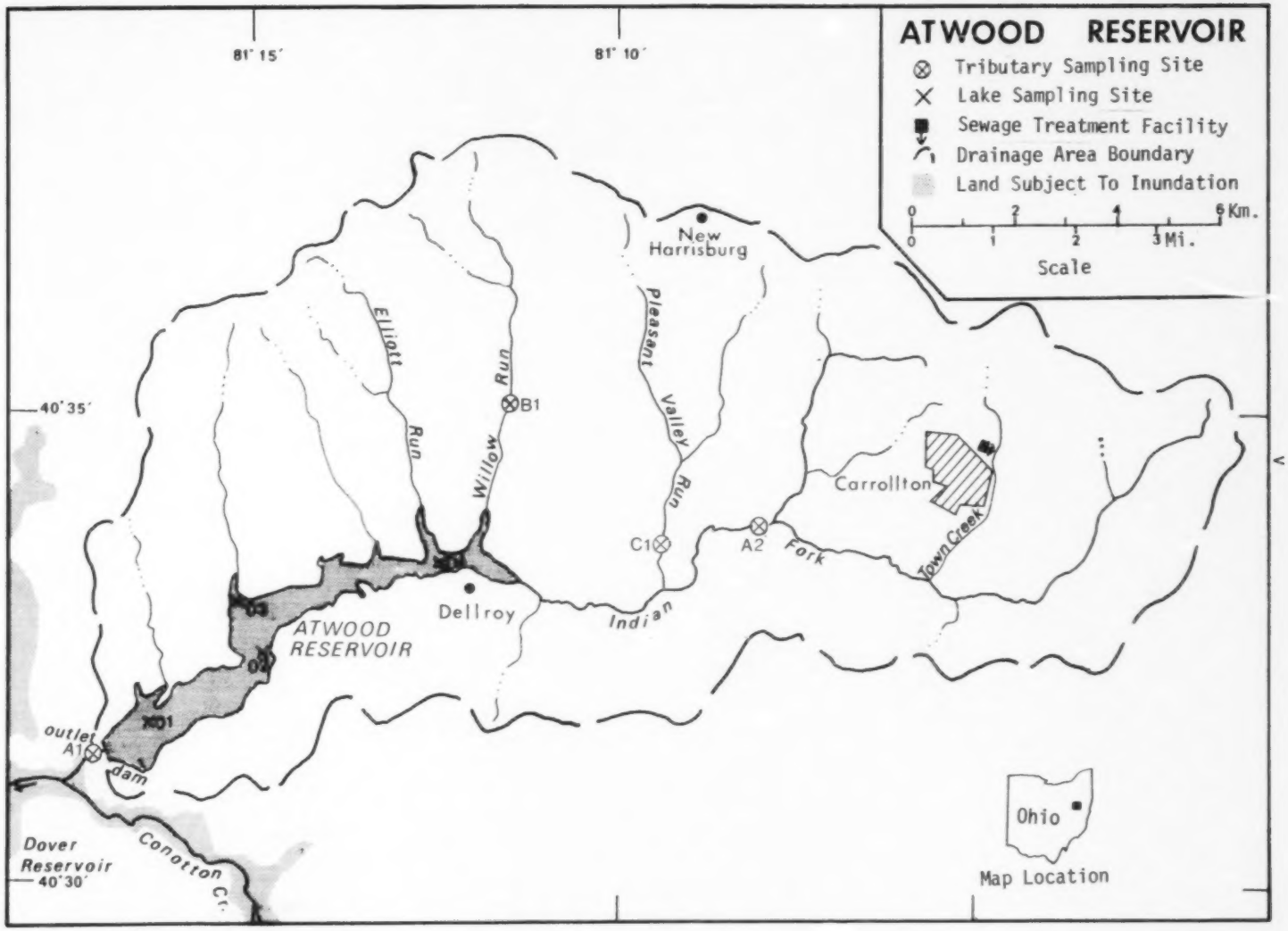
Major General Dana L. Stewart, then the Adjutant General of Ohio, and Project Officer Lt. Colonel Robert C. Timmons, who directed the volunteer efforts of the Ohio National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OHIO

LAKE NAME	COUNTY
Atwood	Carroll, Tuscarawas
Beach City	Stark, Tuscarawas
Berlin	Mahoning, Portage, Stark
Buckeye	Fairfield, Licking, Perry
Charles Mill	Ashland, Richland
Deer Creek	Fayette, Pickaway
Delaware	Delaware
Dillon	Muskingum
Grand Lake of St. Marys	Auglaize, Mercer
Grant	Brown
Holiday	Huron
Hoover	Delaware, Franklin
Indian	Logan
Loramie	Auglaize, Shelby
Mosquito Creek	Trumbull
O'Shaughnessy	Delaware
Pymatuning	Ashtabula, OH; Crawford, PA
Pleasant Hill	Ashland, Richland
Rocky Fork	Highland
Shawnee	Greene
Tappan	Harrison


ATWOOD RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Land Subject To Inundation
0 2 4 6 Km.
0 1 2 3 Mi.
Scale
81° 15'
81° 10'
40° 35'
40° 30'
New Harrisburg
Elliott Run
Willow Run
Pleasant Valley Run
B1
C1
A2
Carrollton
Town Creek
Fork
Indian
Dellroy
ATWOOD RESERVOIR
03
02
01
outlet
A1
dam
Dover Reservoir
Conotton Cr.
Ohio
Map Location

ATWOOD RESERVOIR

STORET NO. 3928

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Atwood Reservoir is eutrophic. It ranked first in overall trophic quality when the 20 Ohio lakes sampled in 1973 were compared using a combination of six lake parameters*. None of the lakes had less median total phosphorus or median dissolved phosphorus, two had less median inorganic nitrogen, six had less mean chlorophyll a, and one had greater mean Secchi disc transparency. Marked depression of dissolved oxygen occurred with depth at station 1 in July.

Survey limnologists noted high numbers of algae at stations 3 and 4 in April and moderate numbers at station 3 in October. Dense submerged vegetation was observed near the shorelines at stations 2 and 3 in October.

B. Rate-Limiting Nutrient:

The algal assay results indicate the reservoir was phosphorus limited at the time the sample was taken (04/20/73). The reservoir data also indicate phosphorus limitation at all sampling stations and times.

C. Nutrient Controllability:

1. Point-sources--More than 24% of the total phosphorus load reaching Atwood Reservoir during the sampling year was contributed by the Carrollton wastewater treatment plant. Septic tanks were estimated to have contributed 0.5% of the total phosphorus load.

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* See Appendix A.

In addition, two industrial point sources discharge to the reservoir via Town Creek/Indian Fork (see page 10). Although no information is available on the nutrient contributions of these sources, they are of probable significance as indicated by the high phosphorus export rate of Indian Fork (see discussion of non-point sources below).

The present loading of 1.67 g $P/m^2/yr$ is more than 2.5 times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 13). A 100% reduction of the phosphorus from the listed point sources would reduce the loading to 1.26 $g/m^2/yr$. Although this loading would still exceed the eutrophic loading, the reduction should at least help slow the rate of deterioration now occurring in the reservoir, particularly if a significant portion of the phosphorus export of Indian Creek also can be controlled.

2. Non-point sources--The phosphorus load from non-point sources was estimated to be 75.1% of the total reaching the reservoir during the sampling year. Indian Fork contributed 62.1%; Pleasant Valley Run, 2.5%; and Willow Run, 1.7%. Minor tributaries and immediate drainage contributed an estimated 7.8% of the total.

Indian Fork appeared to be impacted by sources other than non-point; i.e., the phosphorus export rate was a high 106 $kg/km^2/yr$ (see page 13). This rate is much greater than the rates of the other tributaries; e.g., Pleasant Valley Run (12 $kg/km^2/yr$) and

Willow Run (9 kg/km^2/yr); and indicates that the industrial point sources probably are significant contributors to the total phosphorus load to the reservoir.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 6.23 kilometers^2.
2. Mean depth: 4.7 meters.
3. Maximum depth: >8.2 meters.
4. Volume: 29.281 x 10^6 m^3.
5. Mean hydraulic retention time: 178 days (based on outlet flow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Indian Fork	60.6	0.6
Willow Run	18.9	0.2
Pleasant Valley Run	20.4	0.2
Minor tributaries & immediate drainage -	74.9	0.9
Totals	174.8	1.9

2. Outlet -

Indian Fork	181.0**	2.0

C. Precipitation***:

1. Year of sampling: 96.4 centimeters.
2. Mean annual: 91.3 centimeters.

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† Table of metric conversions--Appendix B.
†† Youger, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Atwood Reservoir was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from four stations on the lake and from one or more depths at each station (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 8.2 meters at station 1, 4.6 meters at station 2, 1.8 meters at station 3, and near-surface only at station 4.

The lake sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR ATWOOD RESERVOIR
STORET CODE 3928

PARAMETER	1ST SAMPLING (4/20/73) 4 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/30/73) 4 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (10/ 8/73) 4 SITES RANGE	MEAN	MEDIAN
TEMP (C)	10.0 - 13.8	12.2	12.7	17.7 - 28.6	24.7	25.0	18.1 - 20.1	19.3	19.6
DISS OXY (MG/L)	10.0 - 12.0	10.8	10.4	0.3 - 13.1	6.9	7.8	5.4 - 9.0	6.9	6.4
CNDCTVY (MCROMO)	220. - 450.	292.	263.	244. - 343.	285.	271.	259. - 404.	287.	261.
PH (STAND UNITS)	7.9 - 8.6	8.4	8.4	7.4 - 9.4	8.1	8.0	7.5 - 8.4	7.8	7.8
TOT ALK (MG/L)	37. - 46.	39.	37.	45. - 69.	50.	47.	52. - 61.	55.	55.
TOT P (MG/L)	0.013 - 0.050	0.020	0.017	0.022 - 0.088	0.040	0.033	0.031 - 0.096	0.045	0.036
ORTHO P (MG/L)	0.003 - 0.007	0.004	0.004	0.004 - 0.011	0.007	0.006	0.004 - 0.009	0.005	0.005
NO2+NO3 (MG/L)	0.730 - 0.970	0.893	0.915	0.050 - 0.120	0.081	0.080	0.040 - 0.130	0.092	0.095
AMMONIA (MG/L)	0.030 - 0.090	0.044	0.040	0.060 - 0.940	0.184	0.090	0.040 - 0.110	0.066	0.070
KJEL N (MG/L)	0.200 - 0.500	0.340	0.350	0.400 - 1.500	0.710	0.600	0.300 - 1.400	0.650	0.600
INORG N (MG/L)	0.770 - 1.060	0.937	0.955	0.110 - 1.060	0.265	0.170	0.090 - 0.210	0.159	0.160
TOTAL N (MG/L)	1.030 - 1.470	1.233	1.185	0.490 - 1.620	0.791	0.680	0.400 - 1.490	0.742	0.700
CHLRPYL A (UG/L)	5.2 - 13.4	8.6	7.8	8.0 - 61.8	24.6	14.2	5.9 - 40.6	16.2	9.1
SECCHI (METERS)	0.3 - 1.7	1.1	1.1	0.4 - 1.2	0.8	0.8	0.7 - 1.2	1.0	1.1

B. Bioligical characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/20/73	1. *Melosira sp.*	973
	2. *Cryptomonas sp.*	608
	3. Centric diatoms	480
	4. *Synedra sp.*	302
	5. Flagellates	262
	Other genera	773
	Total	3,398
07/30/73	1. *Raphidiopsis sp.*	5,656
	2. *Melosira sp.*	5,187
	3. Flagellates	3,156
	4. *Achnanthes sp.*	969
	5. *Cryptomonas sp.*	937
	Other genera	5,032
	Total	20,937
10/08/73	1. *Melosira sp.*	1,251
	2. *Raphidiopsis sp.*	364
	3. *Oscillatoria sp.*	364
	4. *Nitzschia sp.*	364
	5. Flagellates	313
	Other genera	1,513
	Total	4,169

2. Chlorophyll *a* -

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
04/20/73	01	10.3
	02	13.4
	03	5.4
	04	5.2
07/30/73	01	8.1
	02	8.0
	03	20.4
	04	61.8
10/08/73	01	10.1
	02	8.1
	03	5.9
	04	40.6

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.032	0.478	3.6
0.050 P	0.082	0.478	17.0
0.050 P + 1.0 N	0.082	1.478	21.2
1.0 N	0.032	1.478	3.6

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Atwood Reservoir was moderately high at the time the sample was collected (04/20/73). There was a significant increase in yield when orthophosphorus was added but a lack of yield response when nitrogen alone was added. Based on these results, phosphorus limitation is indicated.

The reservoir data also indicate phosphorus limitation; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 18/1 or greater at all sampling stations and times.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Ohio National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of February and March when two samples were collected. Sampling was begun in May, 1973, and was completed in April, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Ohio District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations B-1 and C-1 and multiplying the means by the ZZ area in km^2.

The operator of the Carrollton wastewater treatment plant provided monthly effluent samples and corresponding flow data.

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* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Carrollton	2,900	trickling filter	1,177.8**	Town Creek

2. Known industrial† - There are at least two industrial discharges within the watershed - Affiliated Hospital Products and Olin Corporation - which impact Town Creek. Nutrient loads from these sources are not known but probably are significant (see page 2).

* Rainsberger, 1974.
** Includes industrial wastes.
† Youger, 1975.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Indian Fork	6,445	62.1
Willow Run	175	1.7
Pleasant Valley Run	255	2.5
b. Minor tributaries & immediate drainage (non-point load) -	815	7.8
c. Known municipal STP's -		
Carrollton	2,525	24.3
d. Septic tanks* -	55	0.5
e. Known industrial -		
Affiliated Hospital Prod.	?	-
Olin Corp.	?	-
f. Direct precipitation** -	110	1.1
Total	10,380	100.0

2. Outputs -

Lake outlet - Indian Fork 3,625

3. Net annual P accumulation - 6,755 kg.

* Estimate based on 200 shoreline dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/ yr	% of total
a. Tributaries (non-point load) -		
Indian Fork	65,740	48.5
Willow Run	5,930	4.3
Pleasant Valley Run	13,070	9.6
b. Minor tributaries & immediate drainage (non-point load) -	35,745	26.4
c. Known municipal STP's -		
Carrollton	6,250	4.6
d. Septic tanks* -	2,130	1.6
e. Known industrial -		
Affiliated Hospital Prod.	?	-
Olin Corp.	?	-
f. Direct precipitation** -	6,725	5.0
Total	135,590	100.0

2. Outputs -

Lake outlet - Indian Fork 99,260

3. Net annual N accumulation - 36,330 kg.

* Estimate based on 200 shoreline dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Indian Fork	106	1,085
Willow Run	9	314
Pleasant Valley Run	12	641

E. Yearly Loadings:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	1.67	1.08	21.8	5.8

Vollenweider phosphorus loadings (g/m²/yr) based on mean depth and mean hydraulic retention time of Atwood Reservoir:

"Dangerous" (eutrophic loading)	0.60
"Permissible" (oligotrophic loading)	0.30

V. LITERATURE REVIEWED

Rainsberger, Ira, 1974. Treatment plant questionnaire (Carrollton STP). Carrollton.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Youger, John, 1975. Personal communication (lake morphometry; review of preliminary report). OH Env. Prot. Agency, Columbus.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
3901	BEACH CITY RESERVOIR	0.122	1.990	489.000	10.867	11.600	0.015
3902	BUCKEYE LAKE	0.179	0.380	490.000	186.567	9.600	0.020
3905	CHARLES MILL RESERVOIR	0.127	0.465	482.555	67.144	15.000	0.011
3906	DEER CREEK RESERVOIR	0.098	2.980	470.125	9.887	13.900	0.036
3907	DELAWARE RESERVOIR	0.086	2.340	484.111	10.856	14.500	0.024
3908	DILLION RESERVOIR	0.163	1.590	481.250	27.400	14.300	0.037
3912	GRANT LAKE	0.113	0.570	486.333	40.533	12.200	0.019
3914	HOOVER RESERVOIR	0.040	1.640	462.750	13.017	14.800	0.008
3915	INDIAN LAKE	0.120	0.380	485.222	76.855	14.200	0.012
3917	LORAMIE LAKE	0.185	1.380	494.000	104.100	8.200	0.019
3921	MOSQUITO CREEK RESERVOIR	0.058	0.150	465.333	36.267	11.600	0.006
3924	PLEASANT HILL LAKE	0.036	0.455	456.833	22.850	14.700	0.010
3927	LAKE SAINT MARYS	0.148	0.200	484.167	79.150	8.200	0.014
3928	ATWOOD RESERVOIR	0.031	0.205	462.000	16.442	14.700	0.005
3929	BERLIN RESERVOIR	0.042	0.900	465.435	15.496	13.600	0.006
3930	HOLIDAY LAKE	0.125	0.575	465.333	55.350	15.000	0.034
3931	O'SHAUGNESSY RESERVOIR	0.208	3.070	479.333	5.522	14.900	0.159
3932	ROCKY FORK LAKE	0.067	0.790	473.000	38.022	15.000	0.010
3933	SHAWNEE LAKE	0.069	2.380	474.333	39.567	15.000	0.009
3934	TAPPAN LAKE	0.040	0.280	466.111	37.711	15.000	0.007

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
3901	BEACH CITY RESERVOIR	37 (7)	21 (4)	11 (2)	84 (16)	82 (15)	42 (8)	277
3902	BUCKEYE LAKE	11 (2)	76 (14)	5 (1)	0 (0)	89 (17)	26 (5)	207
3905	CHARLES MILL RESERVOIR	26 (5)	63 (12)	37 (7)	21 (4)	11 (0)	58 (11)	216
3906	DEER CREEK RESERVOIR	53 (10)	5 (1)	63 (12)	95 (18)	63 (12)	11 (2)	290
3907	DELAWARE RESERVOIR	58 (11)	16 (3)	32 (6)	89 (17)	47 (9)	21 (4)	263
3908	DILLION RESERVOIR	16 (3)	32 (6)	42 (8)	58 (11)	53 (10)	5 (1)	206
3912	GRANT LAKE	47 (9)	58 (11)	16 (3)	32 (6)	74 (14)	34 (6)	261
3914	HOOVER RESERVOIR	87 (16)	26 (5)	89 (17)	79 (15)	32 (6)	79 (15)	392
3915	INDIAN LAKE	42 (8)	76 (14)	21 (4)	16 (3)	58 (11)	53 (10)	266
3917	LORAMIE LAKE	5 (1)	37 (7)	0 (0)	5 (1)	97 (18)	34 (6)	178
3921	MOSQUITO CREEK RESERVOIR	74 (14)	100 (19)	82 (15)	53 (10)	82 (15)	92 (17)	483
3924	PLEASANT HILL LAKE	95 (18)	68 (13)	100 (19)	63 (12)	39 (7)	66 (12)	431
3927	LAKE SAINT MARYS	21 (4)	95 (18)	26 (5)	11 (2)	97 (18)	47 (9)	297
3928	ATWOOD RESERVOIR	100 (19)	89 (17)	95 (18)	68 (13)	39 (7)	100 (19)	491
3929	BERLIN RESERVOIR	79 (15)	42 (8)	74 (14)	74 (14)	68 (13)	92 (17)	429
3930	HOLIDAY LAKE	32 (6)	53 (10)	82 (15)	26 (5)	11 (0)	16 (3)	220
3931	O'SHAUGNESSY RESERVOIR	0 (0)	0 (0)	47 (9)	100 (19)	26 (5)	0 (0)	173
3932	ROCKY FORK LAKE	68 (13)	47 (9)	58 (11)	42 (8)	11 (0)	66 (12)	292
3933	SHAWNEE LAKE	63 (12)	11 (2)	53 (10)	37 (7)	11 (0)	74 (14)	249
3934	TAPPAN LAKE	87 (16)	84 (16)	68 (13)	47 (9)	11 (0)	84 (16)	381

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	3928	ATWOOD RESERVOIR	491
2	3921	MOSQUITO CREEK RESERVOIR	483
3	3924	PLEASANT HILL LAKE	431
4	3929	BERLIN RESERVOIR	429
5	3914	HOOVER RESERVOIR	392
6	3934	TAPPAN LAKE	381
7	3927	LAKE SAINT MARYS	297
8	3932	ROCKY FORK LAKE	292
9	3906	DEER CREEK RESERVOIR	290
10	3901	BEACH CITY RESERVOIR	277
11	3915	INDIAN LAKE	266
12	3907	DELAWARE RESERVOIR	263
13	3912	GRANT LAKE	261
14	3933	SHAWNEE LAKE	249
15	3930	HOLIDAY LAKE	220
16	3905	CHARLES MILL RESERVOIR	216
17	3902	BUCKEYE LAKE	207
18	3908	DILLION RESERVOIR	206
19	3917	LORAMIE LAKE	178
20	3931	O'SHAUGNESSY RESERVOIR	173

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR OHIO 1/27/75

LAKE CODE 3928 ATWOOD RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 181.0

NORMALIZED FLOWS(CMS)

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
3928A1	181.0	2.69	2.80	4.02	3.65	2.61	1.50	0.96	0.51	0.37	0.82	1.73	2.10	1.97
3928A2	60.6	1.05	1.27	1.50	1.19	0.71	0.40	0.25	0.18	0.13	0.11	0.28	0.59	0.64
3928B1	18.9	0.31	0.40	0.48	0.40	0.22	0.12	0.08	0.05	0.03	0.03	0.08	0.18	0.20
3928C1	20.4	0.34	0.42	0.51	0.42	0.24	0.13	0.08	0.06	0.04	0.03	0.09	0.20	0.21
3928ZZ	81.3	1.44	1.76	1.98	1.61	0.93	0.54	0.34	0.26	0.18	0.16	0.40	0.82	0.86

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 181.0
SUM OF SUB-DRAINAGE AREAS = 181.2

TOTAL FLOW IN = 23.04
TOTAL FLOW OUT = 23.76

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3928A1	5	73	4.02	5	1.64				
	6	73	1.33	9	2.04				
	7	73	0.34	14	0.25				
	8	73	0.51	11	0.28				
	9	73	0.21	12	0.16				
	10	73	0.62	14	0.54				
	11	73	5.55	11	10.62				
	12	73	5.83	8	1.81				
	1	74	5.35	12	0.18				
	2	74	2.55	13	1.81	27	0.07		
	3	74	0.68	10	0.05	24	1.42		
	4	74	6.97	21	2.21				
3928A2	5	73	1.22	5	0.74				
	6	73	0.48	9	0.42				
	7	73	0.22	14	0.14				
	8	73	0.17	11	0.07				
	9	73	0.10	12	0.07				
	10	73	0.31	14	0.34				
	11	73	1.13	11	0.34				
	12	73	1.44	8	0.48				
	1	74	4.59	12	0.51				
	2	74	0.68	13	0.59	27	0.65		
	3	74	1.44	10	1.73	24	1.02		
	4	74	1.81	21	0.51				

TRIBUTARY FLOW INFORMATION FOR OHIO 1/27/75

LAKE CODE 3928 ATWOOD RESERVOIR

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
3928B1	5	73	0.40	5	0.22				
	6	73	0.14	9	0.14				
	7	73	0.07	14	0.05				
	8	73	0.05	11	0.0				
	9	73	0.03	12	0.01				
	10	73	0.08	14	0.09				
	11	73	0.34	11	0.11				
	12	73	0.42	8	0.15				
	1	74	1.36	12	0.16				
	2	74	0.22	13	0.19	27	0.20		
	3	74	0.45	10	0.54	24	0.31		
	4	74	0.59	21	0.16				
3928C1	5	73	0.42	5	0.24				
	6	73	0.15	9	0.14				
	7	73	0.07	14	0.05				
	8	73	0.05	11	0.02				
	9	73	0.03	12	0.01				
	10	73	0.09	14	0.10				
	11	73	0.37	11	0.12				
	12	73	0.48	8	0.16				
	1	74	1.47	12	0.17				
	2	74	0.23	13	0.20	27	0.22		
	3	74	0.48	10	0.59	24	0.34		
	4	74	0.65	21	0.17				
3928ZZ	5	73	1.61						
	6	73	0.62						
	7	73	0.28						
	8	73	0.25						
	9	73	0.15						
	10	73	0.42						
	11	73	1.59	11	0.0				
	12	73	1.98						
	1	74	0.31						
	2	74	0.93						
	3	74	1.90						
	4	74	2.46						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/01/27

392801
40 31 47.0 081 16 28.0
ATWOOD RESERVOIR
39157 OHIO

TUSCARAWAS
3

2111202
0026 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	15 30	0000	13.2		66	255	8.50	37	0.040	0.400	0.930	0.003
	15 30	0006	11.8	11.6		265	8.40	37	0.030	0.200K	0.920	0.004
	15 30	0015	10.5	10.8		260	8.10	37	0.030	0.200	0.930	0.004
	15 30	0022	10.0	10.3		275	7.90	37	0.040	0.200	0.960	0.005
73/07/30	15 25	0000	25.2		46	270	7.90	47	0.110	0.500	0.080	0.006
	15 25	0005	24.5	7.8		267	7.90	47	0.090	0.500	0.080	0.009
	15 25	0015	24.2	5.8		266	7.50	48	0.140	0.400	0.090	0.007
	15 25	0027	17.7	0.3		244	7.40	69	0.940	1.500	0.120	0.010
73/10/08	14 40	0000	20.1	5.6	48	260	7.60	52	0.040	0.300	0.100	0.004
	14 40	0015	19.8	5.6		259	7.50	53	0.070	0.300	0.130	0.004
	14 40	0024	19.7	5.4		261	7.50	52	0.070	0.600	0.120	0.006

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	15 30	0000	0.016	10.3
	15 30	0006	0.018	
	15 30	0015	0.022	
	15 30	0022	0.020	
73/07/30	15 25	0000	0.023	8.1
	15 25	0005	0.026	
	15 25	0015	0.022	
	15 25	0027	0.067	
73/10/08	14 40	0000	0.032	10.1
	14 40	0015	0.031	
	14 40	0024	0.031	

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/01/27

392802
40 32 36.0 081 15 02.0
ATWOOD RESERVOIR
39019 OHIO

11EPALES
3

2111202
0017 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	16 00	0000	13.7		60	265	8.40	37	0.040	0.500	0.910	0.005
	16 00	0006	12.4	12.0		255	8.60	37	0.040	0.300	0.910	0.005
	16 00	0013	10.8	10.4		260	8.50	37	0.050	0.400	0.910	0.005.
73/07/30	17 00	0000	27.0		36	282	8.60	47	0.090	0.900	0.070	0.011
	17 00	0005	25.1	8.1		272	8.10	46	0.060	0.500	0.050	0.007
	17 00	0014	24.2	4.8		265	7.40	45	0.170	0.500	0.070	0.006
73/10/08	14 15	0000	19.9	8.0	42	261	7.90	55	0.080	0.700	0.080	0.004
	14 15	0015	19.6	5.6		260	7.70	55	0.110	0.500	0.100	0.006

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	16 00	0000	0.013	13.4
	16 00	0006	0.014	
	16 00	0013	0.015	
73/07/30	17 00	0000	0.033	8.0
	17 00	0005	0.033	
	17 00	0014	0.028	
73/10/08	14 15	0000	0.037	8.1
	14 15	0015	0.053	

STORET RETRIEVAL DATE 75/01/27

392803
40 33 28.0 081 15 12.0
ATWOOD RESERVOIR
39019 OHIO

11EPALES
3

2111202
0009 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	16 15	0000	13.8		28	410	8.40	45	0.040	0.400	0.760	0.003
	16 15	0005	13.0	10.4		450	8.50	46	0.040	0.300	0.730	0.003
73/07/30	17 25	0000	25.7		30	343	8.60	47	0.080	0.900	0.080	0.005
	17 25	0004	25.0	8.2		330	8.10	48	0.080	0.700	0.080	0.004
73/10/08	14 00	0000	19.2	9.0	46	286	8.20	56	0.050	0.800	0.040	0.006
	14 00	0006	18.4	7.2		404	8.00	56	0.040	0.600	0.080	0.005

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	16 15	0000	0.015	5.4
	16 15	0005	0.019	
73/07/30	17 25	0000	0.037	20.4
	17 25	0004	0.043	
73/10/08	14 00	0000	0.045	5.9
	14 00	0006	0.036	

STORET RETRIEVAL DATE 75/01/27

392804
40 33 36.0 081 12 27.0
ATWOOD RESERVOIR
39019 OHIO

11EPALES
3

2111202
0005 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/04/20	16 35	0000	13.0	10.0	12	220	8.30	40	0.090	0.500	0.970	0.007
73/07/30	17 40	0000	28.6	13.1	14	314	9.40	54	0.080	0.700	0.090	0.006
73/10/08	13 45	0000	18.1	8.6	28	304	8.40	61	0.070	1.400	0.090	0.009

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/04/20	16 35	0000	0.050	5.2
73/07/30	17 40	0000	0.088	61.8
73/10/08	13 45	0000	0.096	40.6

APPENDIX E

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/03

3928A1
40 31 33.0 081 17 10.0
INDIAN FORK
39011 7.5 MINERAL CITY
O/ATWOOD RESERVOIR
DAM SPILLWAY 1.5 M SE OF NEW CUMBERLAND
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	15 00		0.770	0.900	0.046	0.005K	0.025
73/06/09	09 40		0.026	1.380	0.013	0.005K	0.022
73/07/14	15 15		0.029	2.500	0.690	0.014	0.080
73/08/11	13 45		0.030	1.600	0.920	0.014	0.125
73/09/12	13 37		0.040	1.470	1.050	0.016	0.240
73/10/14	09 45		0.154	0.500	0.050	0.024	0.030
73/11/11	11 15		0.072	0.500	0.028	0.012	0.025
73/12/08	09 53		0.340	0.500	0.036	0.008	0.040
74/01/12	10 04		0.880	0.900	0.112	0.005K	0.025
74/02/13	14 25		1.200	0.500	0.075	0.010	0.040
74/02/27	14 50		1.340	0.500	0.045	0.010	0.060
74/03/10	14 00		1.260	0.500	0.060	0.010	0.050
74/03/24	09 15		1.180	0.500	0.030	0.010	0.025
74/04/21	14 00		0.920	0.400	0.030	0.005	0.035

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

3928A2
40 33 57.0 081 07 50.0
INDIAN FORK
39 7.5 DELROY
1/ATWOOD RESERVOIR
FROM BANK OFF ST RT 39 2 MI NE OF TABOR
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	15 40		1.200	5.050	0.105	0.017	0.810
73/06/09	10 11		0.920	1.650	0.011	0.005K	0.250
73/07/14	15 50		2.600	2.200	0.256	0.680	0.890
73/08/11	14 30		1.920	1.800	0.560	0.760	1.250
73/09/12	14 03		1.660	0.860	0.450	0.530	0.885
73/10/14	10 20		1.020	1.450	0.100	0.115	0.330
73/11/11	11 56		1.800	1.950	0.216	0.370	0.565
73/12/08	10 21		1.900	0.700	0.200	0.128	0.260
74/01/12	11 30		1.680	0.900	0.232	0.060	0.160
74/02/13	14 50		1.600	0.500	0.095	0.060	0.140
74/02/27	15 10		1.180	0.600	0.105	0.075	0.175
74/03/10	14 30		1.430	1.700	0.060	0.045	0.280
74/03/24	09 45		1.320	0.500	0.060	0.050	0.110
74/04/21	14 25		2.500	6.000	1.100	0.055	0.145

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

392881
40 35 10.0 081 11 25.0
#ILLOW RUN
39 7.5 DELROY
T/ATWOOD RESERVOIR
2NDRY RD BRDG 2 MI N OF DELLROY
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	16	10	0.430	0.770	0.044	0.006	0.020
73/06/09	10	30	0.012	0.420	0.005K	0.023	0.025
73/07/14	16	20	0.170	0.890	0.063	0.011	0.025
73/09/12	14	45	0.168	0.610	0.053	0.010	0.060
73/10/14	10	40	0.280	0.650	0.062	0.012	0.015
73/11/11	12	14	0.588	0.100K	0.028		0.011
73/12/08	10	41	0.756	0.100	0.032	0.016	0.035
74/01/12	12	00	0.792	0.100	0.032	0.005K	0.015
74/02/13	14	05	0.704	0.200	0.025	0.005	0.020
74/02/27	15	30	0.740	0.200	0.025	0.005	0.030
74/03/10	14	50	0.720	0.625	0.020	0.005	0.067
74/03/24	10	00	0.672	0.300	0.025	0.010	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

3928C1
40 33 45.0 081 09 20.0
PLEASANT VALLEY RUN
39 7.5 DELROY
T/ATWOOD RESERVOIR
2NDRY RD BRDG 0.8 MI N OF TABOR
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/05/05	15	30	1.200	1.040	0.046	0.006	0.015
73/06/09	10	05	0.010K	1.600	0.005K	0.024	0.045
73/07/14	15	40	0.330	1.050	0.132	0.023	0.080
73/08/11	14	23	0.230	1.250	0.160	0.019	0.085
73/09/12	13	57	0.154	0.270	0.099	0.010	0.060
73/10/14	10	07	0.550	4.000	0.380	0.013	0.075
73/11/11	11	41	1.300	0.150	0.032	0.012	0.012
73/12/08	10	12	1.680	0.100	0.028	0.012	0.012
74/01/12	12	47	1.680	0.600	0.040	0.005K	0.010
74/02/13	14	45	1.600	0.200	0.025	0.005K	0.015
74/02/27	15	05	1.700	0.200	0.020	0.005K	0.030
74/03/10	14	40	1.700	0.500	0.020	0.010	0.065
74/03/24	10	30	1.600	0.300	0.025	0.015	0.015
74/04/21	14	20	0.880	0.300	0.015	0.010	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

3928XA TF3928XA P002900*
40 34 30.0 081 05 00.0
CARROLLTON
39011 250 CANTON
T/AT*OOD LAKE RESERVOIR
TOWN CREEK
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/09/10	08 00								
CP(T)-			6.400	13.200	0.530		9.850	0.190	0.250
73/09/10	15 00								
73/10/23	08 00								
CP(T)-			8.300	8.000		6.075	6.700	0.235	0.230
73/10/23	15 00								
73/11/27	08 00								
CP(T)-			7.000	2.400	0.260	3.200	4.300	0.360	0.300
73/11/27	15 00								
73/12/18	08 00								
CP(T)-			8.200	9.100	0.077	4.300	6.500	0.350	0.380
73/12/18	15 00								
74/01/24	08 00								
CP(T)-			7.200	4.200	0.320	3.200	4.100	0.490	0.450
74/01/24	15 00								
74/02/20	08 00								
CP(T)-			5.200	7.700	1.060	4.400	5.300	0.370	0.350
74/02/20	15 00								
74/03/23	08 00								
CP(T)-			5.700	1.000K	0.590	3.100	3.530	0.480	0.390
74/03/23	15 00								
74/04/26	08 00								
CP(T)-			11.800	6.300	0.300	4.600	6.100	0.250	0.400
74/04/26	15 00								
74/05/23	08 00								
CP(T)-			9.900	6.000	0.370	4.000	5.400	0.430	0.370
74/05/23	15 00								
74/06/20	08 00								
CP(T)-			9.600	8.300	0.059	5.950	7.100	0.250	0.210
74/06/20	15 00								
74/07/25	07 00								
CP(T)-			9.800	8.100	0.210	6.500	8.100	0.175	0.170
74/07/25	15 00								
74/08/23	08 00								
CP(T)-			10.100	12.000	0.150	7.000	8.600	0.210	0.230
74/08/23	15 00								

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/03

3928XA TF3928XA P002900*
40 34 30.0 081 05 00.0
CARROLLTON
39011 250 CANTON
T/ATWOOD LAKE RESERVOIR
TOWN CREEK
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/09/27	08 11								
CP(T)-			8.600	8.400	0.140	6.750	7.500	0.300	0.315
74/09/27	15 00								